DEVELOPMENT OF STATISTICAL PROCESS CONTROL (SPC) MATLAB-BASED SOFTWARE FOR AUTOMOTIVE INDUSTRIES APPLICATION

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ABSTRACT

This project is motivated by an interest in promoting the use computer-based statistical process control (SPC) in manufacturing sector specifically for automotive industries in Malaysia. The use of computer-based SPC is essential in quality function. They are capable to perform various operations or tasks very accurately at fast speeds. SPC techniques are simple statistical techniques to help identify process problems and it can be implemented as simple as analyzing data and plotting charts. However, the development of SPC in Malaysian small and medium-sized enterprises (SMEs) is found lacking because they remain to use traditional SPC techniques which the data are calculated and analyzed manually. Consequently, manual work on traditional SPC has focused on particular limitations; with only little quality faults are detectable, time-consuming and burdensome. This paper highlights the results of an effort to design the SPC computer-based system for conducting simple statistical analysis. The system named as MagNa version 1.0 MATLAB-based software, which is able to offer more benefits to the Malaysian SMEs specifically for automotive industries application.

ABSTRAK

Projek ini adalah di atas dorongan kepentingan dalam menggalakkan penggunaan *Statistical Process Control* (SPC) yang berasaskan komputer dalam sektor pembuatan khususnya untuk industri automotif di Malaysia. Penggunaan komputer berasaskan SPC adalah penting dalam menjalankan fungsi kualiti untuk mencapai piawaian yang ditetapkan. Sistem ini mampu untuk melaksanakan pelbagai operasi atau tugas yang sangat tepat pada kelajuan yang cepat. Teknik SPC merupakan teknik statistik yang mudah untuk membantu mengenalpasti masalah proses dan ia boleh dilaksanakan semudah seperti menganalisis data dan memplot carta. Walau bagaimanapun, pembangunan SPC dalam perusahaan kecil dan sederhana Malaysia (PKS) didapati berkurangan kerana masih ada menggunakan teknik SPC tradisional dimana data dikira dan dianalisis secara manual. Oleh sebab itu, ianya menjurus kepada kerja manual SPC tradisional dimana ianya hanya memberi tumpuan kepada had tertentu, dengan hanya kesilapan kualiti sedikit dikesan, mengambil masa yang lama dan membebankan. Justeru itu, kertas kerja ini membincangkan hasil daripada usaha untuk merekabentuk sistem berasaskan komputer bagi menjalankan analisis statistik dengan mudah. Sistem yang dinamakan sebagai versi Magna 1.0, yang berasaskan perisian MATLAB, mampu untuk menawarkan lebih banyak faedah kepada PKS Malaysia khususnya untuk penggunaan industri automotif.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CL	Centre line
CPL	Lower process capability index
CPU	Upper process capability index
LCL	Lower Control Limit
LSL	Lower Specification Limit
GUI	Graphical User Interface
SPC	Statistical Process Control
UCL	Upper Control Limit
USL	Upper Specification Limit

LIST OF SYMBOLS

μ	Mean
σ	Standard deviation
$\hat{\sigma}$	Estimate of population standard deviation
$\sigma_{\overline{X}}$	Population standard deviation of the subgroup averages
σ_R	Population standard deviation of the subgroup ranges
n	Sample size
m	Number of subgroup
$\bar{x}$	Sample mean
C_p	Process Capability
C_{pk}	Process Cpability Index
$\hat{C}p$	Estimated process capibility
$C\hat{P}L$	Estimated lower process capability index
$C\hat{P}U$	Estimated upper process capability index
$\overline{R}$	Average of the ranges
R_i	Individual range values for the sample
S	Sample standard deviation
$\overline{X}$	Mean of the subgroups
$\overline{\overline{X}}$	Average of the subgroup averages
$\overline{X}_i$	Average of the ith subgroup

LIST OF FORMULA

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION OF STUDY

Quality is a term that carries important meaning to both producer and customer. With ever-increasing demands for improved quality, Statistical Process Control (SPC) is one of the most effective tools of total quality management (TQM). SPC was pioneered by Walter A. Shewhart in the early 1920s at Bell Telephone Laboratories (Charongrattanasakul *et al*., 2011). By definition, SPC is a methodology for monitoring a process to identify special causes of variation and signalling the need to take corrective action when it is appropriate (Evans, 2004).

Under SPC, a process behaves predictably to produce as much conforming product as possible with the least possible waste. In a manufacturing environment, the SPC tool is used for continuous improvement of the production volume as well as quality which leads to achieve manufacturing excellence (Sultana *et al*., 2009). SPC can be applied to all kind of manufacturing operations. The significant application of the SPC analysis elements to the operation will make the process more reliable and stable.

Nowadays, with the movement towards a computer integrated manufacturing environment, computer-based applications need to be developed to implement the various SPC tasks automatically. For this study, MATLAB is using as the computer-based. MATLAB stands for *Matrix Laboratory*. In 2004, MATLAB had around one million users across industry and academia (Goering, 2004).

MATLAB users come from various backgrounds of engineering, science, and economics. MATLAB is widely used in academic and research institutions as well as industrial enterprises. MATLAB was first adopted by researchers and practitioners in control engineering, but quickly spread to many other domains (Goering, 2004). It is now also used in education, in particular the teaching of linear algebra and numerical analysis, and is popular amongst scientists involved in image processing. Cleve Moler, the chairman of the computer-science department at the University of New Mexico, started developing MATLAB in the late 1970s (Goering, 2004).

1.2 PROJECT BACKGROUND

In the global market place today, many organizations realized that its survival in the business world depend highly on bringing high quality product and services to their customers. Due to the global competition, some companies have indeed stressed that quality should have to be put in place, integrated into all aspects of products and services in their management system (Ab Rahman *et al*., 2009). A part of that, SPC is one of the approaches that can be used to ensure continuous quality improvement.

The most successful SPC tool is control chart (Evans, 2004). The control chart is a graph used to study how a process changes over time. Data are plotted in time order. A control chart always has a central line for the average, an upper line for the upper control limit and a lower line for the lower control limit. These lines are determined from historical data. By comparing current data to these lines, we can draw conclusions about whether the process variation is consistent (in control) or is unpredictable (out of control, affected by special causes of variation).

SPC can be applied whenever work is being done. Initially, it was applied to just production processes, but it has evolved to the point where it is applied to any work situation where data can be gathered (Evans, 2004). As companies work toward quality goal, SPC is used in more diverse situations. SPC involves the use of statistical signals to identify the source of variation, to improve performance and to maintain control of processes at higher quality levels. SPC is a powerful tool to optimize the amount of information needed for use in making management decisions.

Some companies nowadays still use manual method to implement SPC in their organization (Ab Rahman *et al*., 2009). More amount of money is needed in almost all industry because they are failed to correct the faults in developing the product at first time (Ribeiro & Cabral, 1999). To reduce the cost and to increase the share market rate, non conformance elimination is the best choice. Most of the system gets failed because they won't confirm that the product is working properly after finishing the product. So this system has to be reprocessed and it needs rework to convert the product into good or confirm condition. This is an extra work and time; money is wasted in huge amount.

Statistical techniques provide an understanding of the business baselines, insights for process improvements, communication of value and results of processes, and active and visible involvement (Evans and Lindsay, 1988). SPC provides real time analysis to establish controllable process baselines; learn, set, and dynamically improve process capabilities; and focus business on areas needing improvement. SPC moves away from opinion-based decision making. These benefits of SPC cannot be obtained immediately by all organizations. SPC requires defined processes and a discipline of following them. It requires a climate in which personnel are not punished when problems are detected and strong management commitment.

1.3 PROBLEM STATEMENT

Currently, computer-based SPC has not been widely used by the small and medium automotive industries. The reason the automotive industry is chosen for this research is because the automotive industry can be considered as one of the most important and strategic industries in the manufacturing sector. Eventually, it has been desired to boost the industrialization process so that Malaysia can be a developed nation by 2020, compared to the other manufacturing sector in Malaysia.

However, there are also many automotive companies remain to use traditional SPC techniques such as calculating and analyzing data manually and also manual charting. Consequently, manual work on traditional SPC has focused on particular limitations; with only little quality faults are detectable, time-consuming and burdensome. The corrective actions by production or quality engineers and technicians are taken only after the occurrence of an out of control signal. By using manual SPC, the number of fault that can be traced is limited. Furthermore, according to production manager, most workers had a very limited background in SPC and less understanding about this concept. They were not properly trained on SPC.

Today, in a global reach towards the use of computer-based especially in automotive sectors, it is important to find a way to quality section to construct control chart using the sustainable methods that will lead in reducing the time. As a concern of that problem, the project is all about to develop the integrated SPC MATLAB-base software. MATLAB is a high-level language and interactive environment that enables to perform computationally intensive tasks faster. MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms and creation of user interfaces (MathWorks, 2012). Thus, it fulfills the requirement of the project in developing the software.

1.4 PROJECT OBJECTIVES

The main objectives of this project are:

i) To develop SPC MATLAB-based software for automotive industry application.

ii) To execute a software that user-friendly and customized for automotive industry.

1.5 PROJECT SCOPES

This project focuses on developing SPC MATLAB-based software which the criteria of this software are must include:

i) The model shall analyze the raw data and its specification being entered into the database in which a control chart will be generated complete with its control limits.

ii) The software shall have its own algorithm to recognize the pattern of the control chart.

iii) The data entered will be able to detect unnatural runs indicating that the process is out-of-control.

iv) The model shall analyze the process capability (C_p) and process performance measurement (C_{pk}).

v) The software shall make crucial comments to the users; notice for corrective action.

In order to develop the reliable software, the information from automotive industries such as their problems and preferred model will be gathering. Also, analysis of the existing computer-based SPC available in the market will be conducted to look at its weakness so that the new model will be a reliable solution. The real data for parts will get from the industries as a sample while run the software.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The purpose of this chapter is to provide a review of past research efforts related to statistical process control (SPC) and the important component in designing the software system for quality control. From the related journal and article, the idea in SPC and designing the software is developed before going further to the next chapter in completing this project.

2.2 STATISTICAL PROCESS CONTROL (SPC)

2.2.1 History of Statistical Process Control (SPC)

The first to apply the newly discovered statistical methods to the problem of quality control was Walter A. Shewhart of the Bell Telephone Laboratories (Charongrattanasakul *et al*., 2011). He issued a memorandum on May 16, 1924 that featured a sketch of a modern control chart. Shewhart kept improving and working on this scheme (Deming, 1975).

2.2.2 Why Statistical Process Control (SPC)

SPC is proven technique for improving quality and productivity (Attaway *et al*., 2011). To avoid non conformance this SPC will closely examine them. This statistical control process will not only help to monitor the process but also it correctly identifies the fault before the delivery of the product (Summers, 2003). The reoccurring problems are eliminated quickly. The significant application of the SPC analysis elements to the operation will make the process more reliable and stable. SPC relies on control charts, one of the basic quality improvement tools.

The most widely used and popular SPC techniques include univariate methods that involve observing a single variable at a given time, obtaining the mean and variance of the variable, and checking its value against upper and lower control limits. While a univariate approach may indeed work for monitoring a small number of process variables that are not correlated, current capabilities in data acquisition hardware allow a large number of variables to be easily measured (Tatara *et al*., 2002).

2.2.3 General Methodology of SPC

The following is a summary of the steps required to develop and use control charts. Steps 1 through 4 focus on establishing a state of statistical control; in step 5, the charts are used for ongoing monitoring; and finally, in step 6, the data are used for process capability analysis (Evans, 2004).

1. Preparation
    a) Choose the variable or attribute to be measured.
    b) Determine the basis, size, and frequency of sampling.
    c) Set up the control chart.
2. Data collection
    a) Record the data
    b) Calculate relevant statistics: average, ranges, and proportions.
    c) Plot the statistics on the chart.
3. Determination of trial control limits
    a) Draw the centre line (process average) on the chart.
    b) Compute the upper and lower control limits.
4. Analysis and interpretation
    a) Investigate the chart for lack of control.
    b) Eliminate out-of-control points.
    c) Recomputed control limits if necessary.

5. Use as a problem-solving tool
    a) Continue data collection and plotting.
    b) Identify out-of-control situations and take corrective action.
6. Determination of process capability using the control chart data

2.2.4 The Basic Tools for SPC

In order to implement continuous improvement in an organization, tools of SPC is quite benefit and essential to them. There are seven tools of SPC (Summers, 2003):

i) Flow Chart;
ii) Pareto Chart;
iii) Check Sheet;
iv) Cause-and-effect diagram;
v) Histogram;
vi) Control chart and
vii) Scatter plot.

For the purpose of this study, control chart is chosen to be implemented as a SPC tool to develop the SPC MATLAB-based software. There is some function of control chart (Summers, 2003):

i) As decision making tools
    - Provide information for timely decision on the products – such as out of control conditions during production, requiring products to be sort and rework.
    - Provide information used to determine process's ability to meet the specification set by the designer – to be used for decision to do continual process improvement.

i) As problem solving tools
    - The control chart help locate the causes of poor quality. By observing the patterns on the chart, the engineer can determine the adjustment required.

- During daily production, the operator can monitor the trend and determine when to make adjustment to the process.

2.3 CONTROL CHART

A control chart is a graphical display of one or more quality characteristic/s versus samples' number or time (Zarandi *et al*., 2010). Typically the chart contains a centre line (*CL*) that represents the in-control value of the quality characteristic, and two limits, namely upper control limit (*UCL*) and lower control limit (*LCL*), which determine the boundaries of the in- and out-of-control conditions which means in some applications the chart may have only one limit (Zarandi et al., 2010). These limits are chosen in a way that if the process is in-control, almost all sample points fall within them.

$\overline{X}$ chart is the most common type of control charts for monitoring the mean of quality characteristics. $CL = \mu$, $UCL = \mu + 3\sigma / \sqrt{n_i}$ and $LCL = \mu + 3\sigma / \sqrt{n_i}$ are the typical control limits of this kind of chart, when the in-control parameters, namely the mean (μ) and the standard deviation (σ) of the quality characteristic are known. $\overline{X_i}$ is the sample statistic plotted on the chart, while n_i is the sample size which is fixed in fixed sampling charts and variable in the variable sampling charts. $\overline{X_i}$ chart is designed to monitor the mean of the quality characteristic, which is usually assumed to follow a normal distribution. To monitor the standard deviation of the process, R chart is employed.

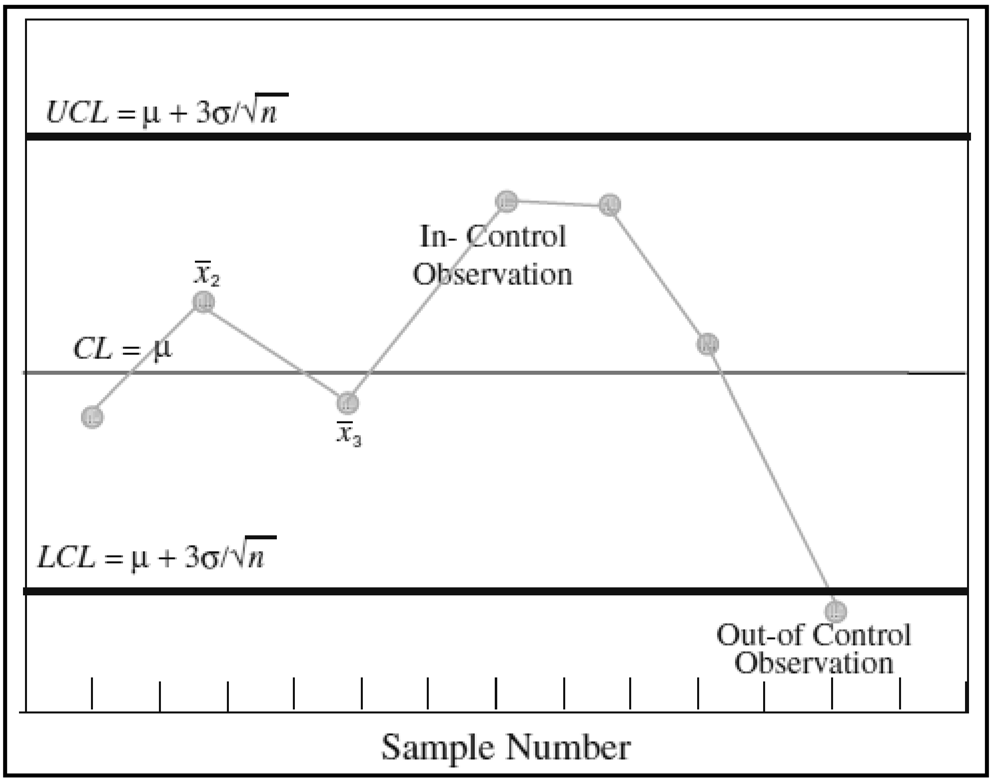

Figure 2.1: Sample of control chart (Zarandi *et al*., 2010)

2.3.1 Control Chart Rule (Western Electric Rule)

In Statistical Process Control, the Western Electric Rules are decision rules for detecting "out-of-control" or non-random conditions on control charts. Locations of the observations relative to the control chart control limits (typically at ±3 standard deviations) and centerline indicate whether the process in question should be investigated for assignable causes. The Western Electric Rules were codified by a specially-appointed committee of the manufacturing division of the Western Electric Company and appeared in the first edition of its Statistical Quality Control Handbook in 1956. Their purpose was to ensure that line workers and engineers interpret control charts in a uniform way.

The rules attempt to distinguish unnatural patterns from natural patterns based on several criteria:

1. The absence of points near the centerline (identified as a mixture pattern).
2. The absence of points near the control limits (identified as a stratification pattern).
3. The presence of points outside the control limits (identified as an instability pattern).
4. Other unnatural patterns (systematic (autocorrelative), repetition, trend patterns).

To achieve this, the rules divide the chart into zones, measured in units of standard deviation (σ) between the centerline and control limits, as follows:

Table 2.1: Divided zone of Western Electric Rule (GMcGlinn, 2009)

Zone	Region
Zone A	Within 2σ of the centerline and the control limit (3σ)
Zone B	Within 1σ and 2σ of the centerline
Zone C	Within 1σ of the centerline

Zones A, B, and C are sometimes called the three sigma zone, two sigma zone, and one sigma zone, respectively. The most important of the Western Electric rules are the zone rules, designed to detect process instability - and the presence of assignable causes. There are four basic rules that deal with appraising runs of observations within the various zones: